GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 9/23/77

Project Title: "Random and Unsteady Combustion Processes in Diesel Engine Noise."

Project No: E-16-628

Project Director: Dr. W. C. Strahle

Sponsor: Energy Research and Development Administration, Oak Ridge Operations

Agreement Period: From 7/1/77 Until 6/30/80 (Contract Period)

Type Agreement: Contract No. EC-77-S-05-5553

Amount: $158,673 ERDA Funds (E-16-628) (Partially funded at $15,000 for first year)
8,688 GIT Contribution (E-16-317)
$167,361

Reports Required: Monthly Technical Progress Letters, Annual Report, Final Report

Sponsor Contact Person (s):

Technical Matters

Dr. Jorgen Birkeland
Combustion Technology Branch
Division of Conservation, Research & Technology
U. S. Energy Research & Devel. Admin.
Washington, D. C. 20545

Contractual Matters
(thru OCA)

A. H. Frost, Jr. Chief
Research Contracts, Procedures and Reports Branch
Contract Division
Oak Ridge Operations
P. O. Box E
Oak Ridge, TN 37830

Defense Priority Rating: None

Assigned to: Aerospace Engineering (School/Laboratory)

COPIES TO:

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- Other

CA-3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 12/1/80

Project Title: Random and Unsteady Combustion Processes in Diesel Engine Noise

Project No: E-16-628

Project Director: Dr. W. C. Strahle

Sponsor: Energy Research & Development Administration, Oak Ridge Operations

Effective Termination Date: 6/30/80

Clearance of Accounting Charges: 6/30/80

Grant/Contract Closeout Actions Remaining:

- X Final Invoice and Closing Documents
- _ Final Fiscal Report
- X Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other _____

Assigned to: Aerospace Engineering (School/Laboratory)

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Project Code (GTRI)
Other _____

CA-4 (1/79)

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

2-
B-53

October 6, 1977

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: First through third monthly progress reports for USERDA contract number EC-77-S-05-5553.

Funding was received in September for the program back-dated to July 1, 1977. For this reason this report covers a three month period. Activity did take place during the summer, although at a reduced pace compared with current activity. The primary tasks were a) familiarization of a new post-doctoral fellow with the Diesel engine equipment and instrumentation b) rebuilding and pressure-sensor installation on a two cylinder, two stroke engine c) conduct of tests to determine acceleration sensitivity of the AVL pressure transducer, and d) Fourier analysis of past results with a focus on the ignition spike portion of the pressure-time trace.

Briefly reviewing, the prior NSF program had conclusively proven that a) the p-t diagram on a single cylinder Deutz engine is sufficiently non-repeatable from cycle to cycle to cause b) a substantial random component to the noise output from such an engine. This non-repeatability has been ascribed to the turbulence of the combustion process. Four fundamental questions existed at the termination of the NSF program. These were a) is the randomness-noise relation primarily driven by the ignition spike or does it come over a large number of crank angle degrees, b) is the randomness due to a randomness in ignition delay or a true randomness in development of the full p-t diagram, c) is the randomness a true property of the p-t diagram or is it caused by vibration sensitivity of the pressure transducer and d) what was the cause of the drop in coherence between the cylinder pressure and noise output during the last run sequence of the NSF program? The initial efforts on the current program are to answer these questions.

Fourier analysis of past results has shown that, indeed, the violent ignition spike contains the primary randomness in the p-t diagram development. Moreover, it is not purely ignition delay randomness but randomness in the full development of the spike that is primarily responsible.

A test sequence has just been completed for vibration sensitivity of the pressure transducer. This data will be analyzed during the next month.

The coherence loss during the runs at high load and with various Cetane fuels is suspected to have been caused by a tape recorder problem. A switch in recorders to a new one with better phase-preservation characteristics has been made. The Cetane rating runs will be repeated, starting next month.

Detroit-Diesel has verbally committed to delivery of an 8-cylinder, two stroke truck engine. Delays in receipt, however, have prompted us to rebuild a two-stroke, two cylinder engine which is on hand. The purpose here is to check the randomness of combustion on a two-stroke cycle as compared with that of the four stroke engine currently in use. This rebuilding process should be completed by mid-October.

The exact plans for the future depend heavily on the outcome of the vibration sensitivity tests for the pressure transducer. Anticipating that a true combustion randomness is being measured, the priority item is a repeat of the Cetane rating runs.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

November 4, 1977

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Fourth monthly progress report for USERDA Contract EC-77-S-05-5553.

During the past report period the major tasks were a) analysis of the vibration sensitivity of the cylinder pressure transducer, b) a repeat test sequence for vibration sensitivity of a new transducer, c) analysis of the noise-cylinder pressure coherence and d) continuation of rebuilding of a two stroke Diesel engine.

It was found that our AVL pressure transducer does, in fact, have vibration response, but that only above 3500Hz does the vibration signal dominate the pressure signal. Consequently, all previously reported results are believed valid to 3500Hz (above which there is no noise problem anyway). To check the generality of this result another test sequence with a capped and uncapped transducer has been conducted with a new transducer. The result will be analyzed during the forthcoming month.

The poor coherence between the noise output and the cylinder pressure which was obtained on the last Cetane rating test sequence has been traced to the acoustic environment of the test room. A microphone location is being sought that will reproduce the high coherence of earlier runs. Moreover, the accelerometer pickup will be favored in the future for showing the causal relation between cylinder pressure and noise.

The rebuilding of the two stroke, two cylinder engine hit a snag when sealing problems between the oil and water lines arose. The cut for the pressure transducer sliced both lines and a satisfactory seal has not been found. We are currently turning the engine into a one-cylinder engine and drilling a more satisfactory pressure access hole in the remaining cylinder.

Delivery of an eight cylinder Detroit Diesel engine has been taken on consignment from General Motors. The engine is complete with drilled head, transmission, clutch, and dynamometer. The cost of set-up will be assessed during the coming month.

Analysis of the combustion randomness-noise relation by a new computational technique has shown that, at mid-load, as much as 75% of the noise output can be directly traced to the combustion randomness. This technique will now be applied to data of previous Cetane rating runs.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

L-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

December 1, 1977

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Fifth monthly progress report for USERDA Contract No. EC-77-5-05-5553

During the past report period the major tasks were a) completion of the analysis of vibration sensitivity of the AVL pressure transducer b) continuation of rebuilding of a two-stroke two-cylinder Diesel engine, and c) initiation of a theoretical effort to extract heat release rate fluctuations from pressure data.

The vibration sensitivity of a second AVL transducer has been analysed and the results found highly similar to those of a first transducer. In the current installation on the Deutz single cylinder engine the signal from the pressure pickup is vibration-dominated above 3500 Hz. While this does not hurt the ability to investigate the cylinder pressure-noise relationship, it does limit the ability to study transverse mode oscillations of the cylinder gases. Prior interpretation of spectral peaks at 4000 and 6000 Hz as transverse modes of the gases was in error.

Because the damage to the cylinder head of the two-cylinder Diesel was so extensive, a surplus engine was procured and the head scavenged. During this month, the second cylinder position of the old head was used for machining "practice" to make sure that when the new head is drilled proper sealing can be attained. The rebuilding should be completed during the next report period.

It is in principle possible to extract turbulence information on the heat release process by the techniques being used. A theoretical effort has been initiated to determine the spatial and frequency resolution attainable as a function of the number of pressure transducers installed in the cylinder head.

Attention is drawn to the fact that the second increment of funding has not been received. Supplies funds are rapidly running out and have been drawn from an institutional account.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

January 4, 1978

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Fifth monthly progress report for USERDA Contract No. EC-77-5-05-5553

During the past report period two major events have hampered progress. These were both financial and technical. First, the lack of the next increment of funding has stalled all rebuilding work and the bringing of the Detroit Diesel V71 on line. There are no supplies funds for this purpose. Secondly, a significant reinterpretation of our results may be in order upon a close examination of past tapes.

Because of the lack of supplies funds, all work currently centers upon more careful analysis of past tape-recorded results. In looking at a comparison of a typical p-t diagram with a 100 cycle average there are several interesting features which have not been observed before, when observing the random deviations from the mean. Near the ignition spike the strongest random deviation of a single trace from the average will usually occur. However, away from the combustion portion of the trace there are indicated $\pm$ 10 psi pressure fluctuations even when the exhaust valve is opened. This is clearly an impossible situation.

Spectral analysis of the random trace away from the combustion portion of the trace reveals a frequency content previously proven to be dominated by the vibration response of the pressure transducer. In the portion of the trace dominated by combustion the frequency content coincides with that previously attributed to combustion noise. However, it has become apparent that the random deviations of each p-t diagram from the average in the combustion region is due to a variation in ignition delay from firing to firing. Since triggering is performed on crank angle, the apparent ignition delay variations can be caused by a) a lack of speed control or b) a true variation in ignition delay. Speed control has been addressed before and has been dismissed as a factor. However, the major finding is that combustion (random) noise is probably not significant in the noise problem but variable ignition delay is. A re-analysis of the cetane variation runs is being made to confirm this point.

A major practical point of this determination is that, if high randomness in the ignition delay is present, it is worthless to examine an average p-t diagram for noise output purposes. It is possible that an engine can have a high dp/dt in the ignition spike on each firing but when averaged over a large number of firings a low dp/dt will result - giving an erroneous

interpretation. It therefore appears necessary to have an idea of both randomness and average p-t behavior to properly interpret noise results. This point will be explored during the next report period.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

February 7, 1978

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Sixth monthly progress report for USERDA
Contract No. EC-77-5-05-5553

The same financial problem as reported during the past two months still exists. The next funding increment has not arrived so that supplies funds are absent. The Detroit Diesel V71 is ready for set-up and instrumentation installation, but no funds are available.

Analysis was continued with old data tapes to clear up some problems in interpretation of the data. The techniques used were a) extremely short time window analysis containing only the ignition spike, b) spectral comparisons of the compression-power stroke with the exhaust-intake stroke, c) triggering of the Fourier time window on pressure rather than crank angle and d) comparison of a high Cetane (low randomness) run with a low power, Diesel Oil No. 2 (high randomness) run. The results may be summarized as follows:

a) Randomness or non-repeatability of the pressure-time trace exists for our direct injection engine, but it is only strong at low power and low to moderate speed. When it is significant it may be easily discerned by visual examination of successive p-t traces. The randomness occurs during ignition and combustion.

b) Apparent randomness during the exhaust and intake strokes is high frequency vibration sensitivity of the pressure transducer.

c) Low randomness at high load, speed and Cetane rating may be unique to the DI method, since high randomness has been observed by other workers with IDI engines.

d) Any degree of randomness will cause a higher noise output at a given engine power output. This has been found significant with our engine, however, only at low power.

e) The signal processing techniques used here can be used as an engine combustion quality diagnostic.

With a view toward forcing a higher degree of cylinder pressure randomness, the small engine will be set up for a test series with a

variable injection timing. This set-up will occur during the coming month.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

E16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

March 3, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Seventh monthly progress report for EC-77-5-05-5553

The same problem as reported in the last three progress reports, that of delayed delivery of the next funding increment, has become acute. Not only have supplies monies been absent but personal services monies have been exhausted. Consequently, until the next increment arrives, personnel have been shifted to other programs. There is no substantive progress to report for this period.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

XC: Al Becker, 2 cys.

E-16-628

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

March 3, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: ~~Seventh~~ Eighth monthly progress report for EC-77-5-05-5553

The same problem as reported in the last three progress reports, that of delayed delivery of the next funding increment, has become acute. Not only have supplies monies been absent but personal services monies have been exhausted. Consequently, until the next increment arrives, personnel have been shifted to other programs. There is no substantive progress to report for this period.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

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GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

April 7, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Ninth monthly progress report for EC-77-5-05-5553

The second funding increment has now been received and work has started again on the project.

The next test sequence on the Deutz Diesel will vary the injection timing. To this end, strain gages have been procured for mounting on the fuel line in order that a measure of injection timing variations may be made. These gages have been received and mounted. The test sequence should be completed during the current month.

The Detroit Diesel V71 with the special heads is in a set-up process. The mounting for the cylinder pressure transducer is being fabricated and the head is being machined. The test stand has been designed and the material procured. Construction of the test stand is underway.

A paper submitted to the 17th Combustion Symposium was accepted and the paper was written during the past month.

Sincerely,

W. C. Strahle
Principal Investigator

cc: J. C. Handley
M. Muthukrishnan
T. M. Dyer
R. M. Law

WCS/cj

E 16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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SCHOOL OF
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

May 5, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Tenth monthly progress report for EC-77-5-05-5553

All machine work for the test stand for the Detroit Diesel V71 has been completed, and the parts are in place awaiting welding. Machining of the pressure transducer holder for cylinder # 1 was begun and the cylinder head is awaiting finishing machining.

Two strain gages were mounted on the fuel line on the Deutz Diesel. This technique proved successful as an indicator of injection timing, so a set of runs was made at five different timing conditions. Instrumentation included cylinder pressure, crank angle, head acceleration, frequency to voltage conversion (speed), three sound microphones, fuel flow, and two strain gages. As check runs to compare with previous data, two runs were made at maximum power and the baseline condition (1800 RPM, 17 ft-lb torque). Commercial fuel was used.

In order to modify the combustion process considerably, ethyl alcohol was mixed with the Diesel fuel in 5% increments from 0-30 %. Six runs with the above instrumentation were made at the baseline condition. All data are currently being subjected to Fourier analysis.

The major tasks for the eleventh month are a) to complete the V71 test stand and cylinder head work and b) to complete Fourier analysis and interpretation of the above tests.

An effort has been reinitiated to determine the feasibility of measurement of the mean square, spectral distribution and spatial correlation length scales of the heat release fluctuation. This is to be accomplished by multiple pressure measurements inside of the cylinder and through use of prior theoretical developments. A senior graduate student is undertaking this task.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
M. Muthukrishnan
T. M. Dyer
W. Hammer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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SCHOOL OF
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

June 8, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Eleventh Monthly Program Report for EC-77-5-05-5553

The test stand for the Detroit Diesel V71 has been completed, the pressure transducer mount has been finished, and the cooling water and exhaust apparatus has been procured. The head is in set-up in the shop for machining. It appears that by the end of the current month the engine will be ready for start-up and no-load testing.

The Fourier analysis of the timing variation and ethyl alcohol additive runs was completed. There were no strong trends in overall noise output with either of these variables. Moreover, the randomness of combustion was not strongly altered. The results at mid-load and mid-speed were that between 25 and 50% of the noise output could be ascribed to cylinder pressure randomness, as previously observed at the nominal timing and Diesel fuel condition.

Construction was completed on a special tube adapter for the pressure transducer mounting hole on the Deutz diesel. The objective here is to see whether a calibration can be achieved between the actual cylinder pressure and the pressure at the end of a long (4"), narrow (3/16") tube. This is necessary if a five tube system is to be installed in the current transducer hole; this set-up is desired in order to extract heat release rate fluctuation data in the cylinder. The theoretical work for the month indicates that ten cross spectral densities from five transducers will be sufficient to extract the necessary fluctuation data. The calibration run will be made during the current month.

A set of runs on the Deutz engine under accelerating conditions is planned for the current month. It is known that dramatic changes take place in overall level of the cylinder pressure spectra under such conditions and it is desired to see if the randomness of the trace is altered under such conditions.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
M. Muthukrishnan
T. M. Dyer
W. Hammer

E/C-628

GEORGIA INSTITUTE OF TECHNOLOGY
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SCHOOL OF
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404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

July 10, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Twelfth Monthly Progress Report for EC-77-5-05-5553

Nine runs were made at various load and speed conditions on the Deutz diesel with the regular cylinder pressure transducer and the one with a tube between the cylinder pressure sensing point and the actual transducer. The purpose is to see whether or not a transfer function can be derived between the two measurements. The tube arrangement is the only design concieved for multiple sensing points without excessive head damage.

The magnitude of the transfer function can be obtained by comparing the two spectra. The phase, although it may not even be needed, presents a more difficult measurement problem. A unique method has been devised for this measurement based upon looking at the transfer functions of the two pressure measurements against a common element - the cylinder head vibration measurement. The Fourier analysis of the nine runs will be completed this month and the adequacy of the method will be evaluated.

Some shop delays have delayed the start up of the Detroit Diesel V71. The optical encoder flange, and exhaust gas adapter flange are still to be fabricated, although the head machining and transducer holder fabrication are complete. The engine has been mounted on the test stand. Some delay has also been encountered in the cooling water set-up. Before start-up, a certification will also have to be supplied by a General Motors representative. Consequently, it now appears that a useful data-taking run will be delayed until mid-August.

A closer look at the planned set of accleration runs on the Deutz diesel revealed ambiguities in the meaning of the type of Fourier analysis we have been conducting. Consequently, the acceleration runs will not be made.

The tasks for the 13th month include a) continuation of set-up of the V71 engine and b) Fourier analysis of the runs with the special transducer mount.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj
cc: J. C. Handley
W. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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SCHOOL OF
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404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

August 4, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington DC 20545

Subject: Thirteenth monthly progress report for EC-77-5-05-5553

The Fourier analysis of the cylinder pressure measurements with the transducer located either in the head or at the end of a connecting tube was completed. Three conditions were analyzed - idle (1000 RPM, no load), mid-range (1800 RPM, 17 ft-lb torque) and maximum speed (3000 RPM, 23 ft-lb). The objective was to see if a linear transfer function exists between the two measurement points. Division of the two auto spectra should give the square of the magnitude of the transfer function. Division of the transfer functions between the two pressure measurements and the head vibration should give the magnitude and phase of the desired transfer function. Comparison of the two derived magnitudes should indicate the "goodness" of the assumption that the linear transfer function exists. In all cases it was found that such a relation does exist, although the mid-range condition gave the best results. This result was surprising and highly satisfying. It opens the door for multiple point measurements of the cylinder pressure and deduction of several characteristics of the turbulence of the combustion process.

Work has continued on the set-up of the 8V71 Detroit diesel. All gaskets, seals and special tools were obtained for complete reassembly of the engine. A laboratory modification to the cooling water supply was judged necessary, and, since this must be done by the Georgia Tech Physical Plant, some delay will be encountered. Some machining on the optical encoder adapter flange and exhaust gas adapter flange remains to be done.

The major task for the 14th month is to complete set-up of the 8V71 and obtain idle, no-load data on the cylinder pressure.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

September 5, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington DC 20545

Subject: Fourteenth monthly progress report for EC-77-5-05-5553

Work on set-up of the Detroit Diesel 8V71 engine has been completed. Two heat exchangers were adapted to use for the engine cooling water. The laboratory cooling water system was modified for hookup to the system. Complete reassembly of the engine was affected and the exhaust line to the building exterior was installed. All valve and injector settings have been completed. We are waiting for Dixie Engine (a GM representative) representative to check out the engine. Initial tests at no load over a range of speed will be completed this month.

A design was submitted to the machine shop for a five-transducer assembly for simultaneous measurement of pressure at five closely spaced cylinder points on the Deutz diesel. What is aimed at is a direct demonstration that in certain frequency ranges the cylinder pressure is not uniform across the cylinder, but that spacewise variations, random in nature, actually occur. The design for this probe is based upon the results, reported last month, on the extended tube probe. Fabrication will take about one month.

A paper on the results to data on the Deutz diesel was presented at the 17th International Combustion Symposium.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

E16428

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

October 4, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Fifteenth monthly progress report for EC-77-5-05-5553

The first runs on the Detroit Diesel 8V-71T engine were completed and preliminary results at one condition were obtained through Fourier analysis. A contractor's meeting was attended and results were reported for the previous year's activity. Work continued on the extraction of turbulence properties from the cylinder pressure measurement.

The Detroit Diesel engine installation was approved by Dixie Engine. Final modifications made were installation of several pressure and temperature guages, throttle control and the optical encoder. Runs were made at no load over the full speed range of the engine with the following instrumentation: a) cylinder pressure in cylinder # 1, b) optical encoder at 1 pulse/CA^{o}, 1 pulse/360 CA^{o} and frequency to voltage conversion, c) noise at 1m to the side of the engine. Motored runs were also conducted by removing fuel from cylinder # 1 and running on 7 cylinders. Data reduction was completed for the idle condition.

The results at idle are surprising. The cylinder pressure becomes random above 500 Hz, whereas the previous Deutz diesel results were only random above 1000 Hz. Moreover, there was fair coherence between the noise and the single cylinder pressure measurement. Of the coherent noise, 64% was random. We are anxiously awaiting the data reduction at the other condition to see if this difference between the two stroke and the four stroke engines persists.

The relatively high coherence between the noise and the single cylinder measurement are prompting the formulation of plans for multicylinder, multiple coherence measurements. Moreover, the high randomness on the Detroit Diesel engine suggests the use of this engine for investigation of turbulence through pressure measurements.

Machining was initiated on the five-tube pressure transducer assembly.

Supplies funds have been exhausted and personal services funds will become exhausted in December. At that time, if word of the next funding increment is not received, personnel layoffs will be incurred.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

November 8, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Sixteenth monthly progress report for EC-77-5-05-5553

Data reduction on the initial runs of the Detroit Diesel 8V71T engine was completed. The machining on the 5-tube pressure transducer assembly was completed. Theoretical work on the extraction of turbulence properties from the pressure measurement continued.

An error was discovered in the reported findings in the last monthly progress report. The results reported were at 2300 RPM, no-load rather than at idle. Data reduction was completed for three runs, all at no load; these were at 500, 1370 and 2300 RPM. Moreover, data reduction for the motoring condition (fuel shut off to cylinder number R1) at the same speeds was completed. The data at the idle condition of 500 RPM had to be rejected because there was no evidence of combustion in the monitored cylinder. Evidently, an injector setting was at fault.

There was little difference between the motoring and fuel-on runs. Upon looking at the p-t trace there was also little combustion taking place even at the full speed condition. Interestingly, the fraction of sound output coherent with the R1 cylinder pressure was high and the fraction of the sound due to randomness was also high. However, to get interesting combustion results will require that the engine be loaded up. Efforts in this direction were initiated.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

E-16-628

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ATLANTA, GEORGIA 30332

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

December 7, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Seventeenth monthly progress report for EC-77-5-05-5553

Work continued on the connection of the clutch-transmission-dynomometer to the Detroit Diesel 8V71T engine. However, the lack of funding slowed the effort since one engineer was transferred to another project. The entire effort is now being carried on institutional funding.

The five transducer pressure assembly was checked out and found to be defective in two transducer channels, due to the transducer-cable assemblies and not the apparatus. One new cable was ordered and has been received. Initial tests with this configuration will begin this month.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

EC-C-28

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

February 5, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Eighteenth and Nineteenth monthly progress reports for
EC-77-5-05-5553

Work continued on the hookup to load for the 8V71T engine. The clutch-transmission-dynamometer installation was completed. The engine cooling water system and the dynamometer water supply systems were installed. Large leaks were found in the heat exchange system and these were repaired. A cooler for the fuel system was designed and is currently being machined.

The five transducer assembly for the Deutz diesel was tested with all pressure transducers installed. The five tube connections to the main cylinder head fitting were too weak in the face of the engine vibration, and the assembly failed. A redesign was made to stiffen the entire structure of the assembly and a new device is being manufactured.

Word was received from the DOE contract office that the paper work for the next funding increment has been initiated. Accordingly, steps have been taken to assure continuity of work on the project.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

March 7, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twentieth monthly progress report for EC-77-5-05-5553

Installation of the 8V71T engine was completed during the current month. Checkout of the coolng system, fuel cooling system, and dynamometer was completed. Initial indications of the cylinder pressure at high load are that there is extreme randomness in the p-t trace. Runs over a range of load and speed will be made during the coming month.

The five transducer assembly for the Deutz diesel was redesigned and manufactured. The assembly has been considerably stiffened to avoid failure. The cross spectral density information required to analyze the heat release rate spectrum has been theoretically investigated to estimate accuracy of the measurement. It has been found that actual test data on the coherence between transducers are needed to estimate the accuracy, so that initial runs will be made to obtain the necessary numbers. These runs will be made during the coming month.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

April 3, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twenty-first monthly progress report on EC-77-5-05-5553

Results were obtained on the 8V71T engine at three conditions of partial load at high speed. The power range was 51-191 HP over a speed range of 1740-2270 RPM. The engine makes noise centered about 1000 Hz with a minor speed-dependent peak due to the turbocharger. A significant fraction of the noise is coherent with the cylinder pressure, which was known from other programs with this engine. What is new, however, is that a significant portion of the coherent noise (1/3) is random in nature, not periodic.

Because a single cylinder of the eight cylinders is being monitored, there are some modifications which must be made in usual coherence analysis in order to interpret the results. These relationships are currently being worked out. The major finding of randomness, however, is important because it has now been shown on both of our test engines - one a four stroke and one a two stroke.

A more systematic set of runs over a range of load and speed will be made during the coming month. Some delays may be encountered, however, because of control difficulties with the dynamometer. Some modification of the water discharge may have to be made. The difficulties have arisen in tests near maximum power.

Test runs on the five transducer assembly for the Deutz diesel have shown some initial results that are relatively curious. Coherence between transducers separated by less than 1/4 inch has dropped off at quite low frequencies (1000 Hz). Significant gradients in random pressure were not expected until about 3000 Hz. These results, if valid, will require modifications of the theory used to interpret the results. Checks are currently being made on the data validity and accuracy.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

May 7, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C.

Subject: Twenty second monthly progress report on EC-77-S-05-5553

A further high load (316 HP) result was obtained with the 8V71T engine. A technique was developed to estimate the multiple coherence function of the eight cylinder pressures to the sound pressure when only using a single cylinder pressure measurement. The four runs made on the engine were subjected to analyses by this technique but an error was discovered in the data analysis and it wil have to be redone.

A modification was made to the dynamometer water control which will allow more positive control of load and speed. Consequently, the runs with a systematic variation of load and speed have been postponed until the coming month.

Confirmation was gained on the five transducer assembly that microphones spaced less than 1/4" apart suffer significant coherence loss at 1000 Hz. This is indicating strong local nonlinearities in the development of cylinder pressure which were not expected. An initial attempt has been made to measure transfer function between the actual cylinder pressure and the transducer assembly sensed pressure. Moreover, checks are being run on the pressure transducer vibration response. These initial checks should be completed during the coming month.

A new type recorder, non-portable in nature, is being installed in the laboratory which should alleviate some severe scheduling problems with the current portable recorder. Results are now expected to increase in volume.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E 16-628

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SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

June 11, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twenty third monthly progress report on EC-77-S-05-5553

Reanalysis of four runs of the 8V71T engine has revealed conclusions which are in line with the older runs on the single cylinder Deutz engine. For all runs the minimum fraction of the radiated noise which is coherent with the cylinder pressure is of the order of one-half; of this noise at least 30% is random in nature, not periodic. Speed control was not particularly good on these runs and limits the conclusions to frequencies below 6000 Hz. This excludes turbocharger noise.

Four additional runs with a systematic variation of load at fixed speed were accomplished during the past month. Speed variations at fixed load will be attempted during the coming month. Some control difficulties at high power are still being encountered; these difficulties involve the simultaneous control of engine cooling and dynamometer outlet water temperature. Studies are underway to suggest instrumentation to alleviate the problem (which usually manifests itself by a burst engine water line).

The five transducer assembly for the Deutz diesel was tested for transducer vibration response and found to suffer loss of pressure sensitivity (too much vibration sensitivity) above 2500 Hz. This is somewhat lower in frequency than was found for the flush mounted transducer, but still adequate for the study in mind. The loss in coherence between closely spaced transducers, which occurs above about 700 Hz, is adequately covered by the frequency range available. The difference in signals between the neighboring microphones has been found to be above the range of statistical uncertainty so that the result appears real. In order to extract heat release rate fluctuation data, however, a second space derivative of pressure must be constructed and current investigation is centered about the statistical certainty of such a measurement.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

July 6, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twenty fourth monthly progress report on EC-77-S-05-5553

Vacations and equipment failures hampered progress for the month. Tape recorder, charge amplifier and amplifier cable difficulties coupled with a temporary shortage of manpower in the instrumentation repair laboratory have made it impossible to make substantial progress for the month. Moreover, the desire for better temperature readout on the GM diesel has caused a delay in further testing while the decision was made to purchase the necessary instrumentation.

Analysis of the implied pressure gradient fluctuation for closely spaced transducers on the Deutz engine has revealed pressure gradients which are unrealistic. However, the prior result on coherence loss between these transducers is believed valid, so a discrepancy between experimental results and physical intuition has been uncovered. A test series has been planned for the coming month to resolve this difficulty.

The runs on the GM diesel at fixed speed will be subjected to Fourier analysis during the coming month.

Sincerely

Warren C. Strahle
Principal Investigator

WCS/jj
cc: J. C. Handley
W. C. Hammer
T. M. Dyer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

September 11, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: 26th Monthly Progress Report on EC-77-S-05-5553

The pressure transducer cap for the 8V71T engine was designed and submitted to the shop. This cap, designed to isolate the sensing element to check vibration sensitivity, caused more design difficulty than anticipated because of very low clearances in this engine. The data on the Fourier analysis on all runs was reviewed with a view in mind to see any trends of the results with load and speed. As previously reported, there are no clear trends.

Repeated failures have occurred with the five transducer assembly for the Deutz engine. The primary difficulty is in keeping leaks from developing in the attachment of the remote sensing tube to the cylinder head fitting. Moreover, in one run which would have been successful, there turned out to be a problem in the recording of the head accelerometer trace. Without this signal it is impossible to extract the sensed-to-true cylinder pressure transfer function. Pursuit of the required measurement is continuing.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E-110-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

October 5, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: 27th Monthly Progress Report on EC-77-S-05-5553

The cylinder pressure transducer holder for the 8V71T engine, which was designed to cap the sensing element, was completed and installed. Two runs were made to establish the vibration sensitivity of the transducer. Fourier analysis of the runs is not complete, but, judging from the rms signal level, which was only slightly above the electronic noise level, the conclusions will be the same as with the Deutz engine - the vibration response is not sufficient to invalidate prior conclusions with regard to the cylinder pressure measurements.

Problems were overcome with the five transducer assembly on the Deutz engine and a successful run was achieved. The run consisted of one test with a single flush-mounted transducer and a head accelerometer followed by a test with three remote pressure transducers and a head accelerometer. As previously reported, the trick here for calibration is to obtain transfer functions between the flush mount and accelerometer and then between the remotes and accelerometer. This yields the remote transducers calibration to true pressure.

Confirmation of a prior surprising result was achieved. There is a loss of coherence between two closely spaced transducers (1/8 inch) above about 800 Hz. Moreover, the phase between transducers is random, indicating a variation in firing-to-firing ignition site location. If this is true and if, furthermore, each firing consists of multiple, randomly located ignition sites, then the engine vibration can be expected to be larger than if the entire cylinder pressure developed uniformly in space. There would consequently be more noise. This conclusion suggests that a preferred ignition site should be introduced into the cylinder from, for example, a spark. These results will be tested in the near future.

The above conclusions are still tentative, however, because several checks must be made on the Fourier analysis. Operation is being demanded over a wide dynamic range and the generation of the necessary cross spectral densities is taking place at the accuracy limits of the A to D converter, tape recorder, computer and statistical procedure. During the current months the confidence limits of the results will be established.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
T. M. Dyer
W. G. Hammer

E-16-628

GEORGIA INSTITUTE OF TECHNOLOGY
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SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

November 13, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Dept. of Energy
Washington, D.C. 20545

Subject: 28th Monthly Progress Report on EC-77-S-05-5553

Fourier analysis was completed of the capped transducer runs for the 8V71T engine. The vibration signal of the pressure transducer was significantly lower than on the Deutz engine, and, consequently, the cylinder pressure results can be believed out to about 6000 Hz. However, during data analysis a 60 cycle problem was found with the tape recorder upon playback, and the problem may have contaminated some earlier analysis work on the cylinder pressure. Consequently, a reanalysis will be performed during the coming month.

Statistical analysis of the results on the five transducer assembly for the Deutz engine has revealed the disappointing results that prior conclusions cannot be justified with any statistical confidence. The accuracy limits of analysis are insufficient to resolve the differences in pressure of measurement points spaced 1/8 inch apart. The cylinder head has been returned to the shop for installation of the widely spaced transducers in order to investigate the spatial variation in cylinder pressure.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: T.M. Dyer
J.C. Handley
W. G. Hammer

A-76-628

Final Report

Random and Unsteady Combustion Processes in Diesel Engine Noise

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Dept. of Energy Contract No. DE-AS05-77ET11342 GIT Project No. E16-628

Warren C. Strahle
Principal Investigator

History

The contract was initiated on 7/1/77 and was to proceed through 6/30/80. The final increment of funding was not received; consequently, work terminated on 10/31/79. The required monthly progress reports were filed through that date.

Accomplishments

The detailed accomplishments are documented in the attached monthly progress reports. Insofar as hardware and data analysis development were concerned, the primary accomplishments follow:

1. Installation of a 350 HP Detroit Diesel 8V71T engine with transmission and dynamometer
2. Development of technique for estimating multi-cylinder coherence with generated noise when using a pressure monitor on only one cylinder
3. Development of technique for remote sensing of cylinder pressure at multiple cylinder points.

The primary technical goal was to demonstrate that a significant part of the cylinder pressure spectrum in diesel engines is caused by random, not periodic, pressure fluctuations and that these random fluctuations cause a substantial amount of noise. Tasks were carried out on two engines -a single cylinder four stroke and an eight cylinder two stroke engine. For the four stroke engine it was found that between 25 and 50% of the noise radiated was indeed due to the random cylinder pressure fluctuations. For the two stroke engine, only about 25% of the noise could be ascribed to this effect.

Variables investigated on both engines were load and speed. Additional variables checked on the single cylinder engine were injection timing and alcohol addition. In all cases the results were checked for contamination of the signal due to transducer vibration. Multiple analysis methods were applied to the data to assure validity.

The primary results of the work on the single cylinder engine were published as

Strahle, W. C., Muthukrishnan, M. and Handley, J. C., "Turbulent Combustion and Diesel Engine Noise," Seventeenth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh (1979) pp. 337-345.

The results on the eight cylinder engine have not been published due to lack of funds.

GEORGIA INSTITUTE OF TECHNOLOGY
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

November 13, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Dept. of Energy
Washington, D.C. 20545

Subject: 28th Monthly Progress Report on EC-77-S-05-5553

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Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: T.M. Dyer
J.C. Handley
W. G. Hammer

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

October 5, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: 27th Monthly Progress Report on EC-77-S-05-5553

The cylinder pressure transducer holder for the 8V71T engine, which was designed to cap the sensing element, was completed and installed. Two runs were made to establish the vibration sensitivity of the transducer. Fourier analysis of the runs is not complete, but, judging from the rms signal level, which was only slightly above the electronic noise level, the conclusions will be the same as with the Deutz engine - the vibration response is not sufficient to invalidate prior conclusions with regard to the cylinder pressure measurements.

Problems were overcome with the five transducer assembly on the Deutz engine and a successful run was achieved. The run consisted of one test with a single flush-mounted transducer and a head accelerometer followed by a test with three remote pressure transducers and a head accelerometer. As previously reported, the trick here for calibration is to obtain transfer functions between the flush mount and accelerometer and then between the remotes and accelerometer. This yields the remote transducers calibration to true pressure.

Confirmation of a prior surprising result was achieved. There is a loss of coherence between two closely spaced transducers (1/8 inch) above about 800 Hz. Moreover, the phase between transducers is random, indicating a variation in firing-to-firing ignition site location. If this is true and if, furthermore, each firing consists of multiple, randomly located ignition sites, then the engine vibration can be expected to be larger than if the entire cylinder pressure developed uniformly in space. There would consequently be more noise. This conclusion suggests that a preferred ignition site should be introduced into the cylinder from, for example, a spark. These results will be tested in the near future.

The above conclusions are still tentative, however, because several checks must be made on the Fourier analysis. Operation is being demanded over a wide dynamic range and the generation of the necessary cross spectral densities is taking place at the accuracy limits of the A to D converter, tape recorder, computer and statistical procedure. During the current months the confidence limits of the results will be established.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
T. M. Dyer
W. G. Hammer

628 Report

September 11, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: 26th Monthly Progress Report on EC-77-S-05-5553

The pressure transducer cap for the 8V71T engine was designed and submitted to the shop. This cap, designed to isolate the sensing element to check vibration sensitivity, caused more design difficulty than anticipated because of very low clearances in this engine. The data on the Fourier analysis on all runs was reviewed with a view in mind to see any trends of the results with load and speed. As previously reported, there are no clear trends.

Repeated failures have occurred with the five transducer assembly for the Deutz engine. The primary difficulty is in keeping leaks from developing in the attachment of the remote sensing tube to the cylinder head fitting. Moreover, in one run which would have been successful, there turned out to be a problem in the recording of the head accelerometer trace. Without this signal it is impossible to extract the sensed-to-true cylinder pressure transfer function. Pursuit of the required measurement is continuing.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

E16-628 reports

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

August 6, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D. C. 20545

Subject: 25th monthly progress report on EC-77-S-05-5553

Fourier analysis on 8V1T runs was completed for two runs conducted in June and for seven new runs conducted during the past month. A full range of speed and power has now been fully covered. The basic result, subject to some data scatter, is insensitive to load and speed; about one half of the radiated noise is coherent with the cylinder pressure and about 30% of this noise is random, not periodic.

It now remains to check the vibration sensitivity of the transducer, which will be done during the coming month. Final work on this contract with the large engine will then investigate cylinder to cyliner coherence of the pressure to verify random behavior.

A new five transducer assembly had to be designed for the Deutz engine due to a failure. Manufacture has proceeded during the past run and the runs to check coherence on closely spaced measurement points will be made during the coming month.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

July 6, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twenty fourth monthly progress report on EC-77-S-05-5553

Vacations and equipment failures hampered progress for the month. Tape recorder, charge amplifier and amplifier cable difficulties coupled with a temporary shortage of manpower in the instrumentation repair laboratory have made it impossible to make substantial progress for the month. Moreover, the desire for better temperature readout on the GM diesel has caused a delay in further testing while the decision was made to purchase the necessary instrumentation.

Analysis of the implied pressure gradient fluctuation for closely spaced transducers on the Deutz engine has revealed pressure gradients which are unrealistic. However, the prior result on coherence loss between these transducers is believed valid, so a discrepancy between experimental results and physical intuition has been uncovered. A test series has been planned for the coming month to resolve this difficulty.

The runs on the GM diesel at fixed speed will be subjected to Fourier analysis during the coming month.

Sincerely

Warren C. Strahle
Principal Investigator

WCS/jj
cc: J. C. Handley
W. C. Hammer
T. M. Dyer

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
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404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

June 11, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twenty third monthly progress report on EC-77-S-05-5553

Reanalysis of four runs of the 8V71T engine has revealed conclusions which are in line with the older runs on the single cylinder Deutz engine. For all runs the minimum fraction of the radiated noise which is coherent with the cylinder pressure is of the order of one-half; of this noise at least 30% is random in nature, not periodic. Speed control was not particularly good on these runs and limits the conclusions to frequencies below 6000 Hz. This excludes turbocharger noise.

Four additional runs with a systematic variation of load at fixed speed were accomplished during the past month. Speed variations at fixed load will be attempted during the coming month. Some control difficulties at high power are still being encountered; these difficulties involve the simultaneous control of engine cooling and dynamometer outlet water temperature. Studies are underway to suggest instrumentation to alleviate the problem (which usually manifests itself by a burst engine water line).

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Sincerely,

Warren C. Strahle
Principal Investigator

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W. G. Hammer
T. M. Dyer

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

May 7, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C.

Subject: Twenty second monthly progress report on EC-77-S-05-5553

A further high load (316 HP) result was obtained with the 8V71T engine. A technique was developed to estimate the multiple coherence function of the eight cylinder pressures to the sound pressure when only using a single cylinder pressure measurement. The four runs made on the engine were subjected to analyses by this technique but an error was discovered in the data analysis and it wil have to be redone.

A modification was made to the dynamometer water control which will allow more positive control of load and speed. Consequently, the runs with a systematic variation of load and speed have been postponed until the coming month.

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A new type recorder, non-portable in nature, is being installed in the laboratory which should alleviate some severe scheduling problems with the current portable recorder. Results are now expected to increase in volume.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

April 3, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twenty-first monthly progress report on EC-77-S-05-5553

Results were obtained on the 8V71T engine at three conditions of partial load at high speed. The power range was 51-191 HP over a speed range of 1740-2270 RPM. The engine makes noise centered about 1000 Hz with a minor speed-dependent peak due to the turbocharger. A significant fraction of the noise is coherent with the cylinder pressure, which was known from other programs with this engine. What is new, however, is that a significant portion of the coherent noise (1/3) is random in nature, not periodic.

Because a single cylinder of the eight cylinders is being monitored, there are some modifications which must be made in usual coherence analysis in order to interpret the results. These relationships are currently being worked out. The major finding of randomness, however, is important because it has now been shown on both of our test engines - one a four stroke and one a two stroke.

A more systematic set of runs over a range of load and speed will be made during the coming month. Some delays may be encountered, however, because of control difficulties with the dynamometer. Some modification of the water discharge may have to be made. The difficulties have arisen in tests near maximum power.

Test runs on the five transducer assembly for the Deutz diesel have shown some initial results that are relatively curious. Coherence between transducers separated by less than 1/4 inch has dropped off at quite low frequencies (1000 Hz). Significant gradients in random pressure were not expected until about 3000 Hz. These results, if valid, will require modifications of the theory used to interpret the results. Checks are currently being made on the data validity and accuracy.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

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SCHOOL OF
AEROSPACE ENGINEERING

404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

March 7, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Twentieth monthly progress report for EC-77-5-05-5553

Installation of the 8V71T engine was completed during the current month. Checkout of the coolng system, fuel cooling system, and dynamometer was completed. Initial indications of the cylinder pressure at high load are that there is extreme randomness in the p-t trace. Runs over a range of load and speed will be made during the coming month.

The five transducer assembly for the Deutz diesel was redesigned and manufactured. The assembly has been considerably stiffened to avoid failure. The cross spectral density information required to analyze the heat release rate spectrum has been theoretically investigated to estimate accuracy of the measurement. It has been found that actual test data on the coherence between transducers are needed to estimate the accuracy, so that initial runs will be made to obtain the necessary numbers. These runs will be made during the coming month.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

February 5, 1979

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Eighteenth and Nineteenth monthly progress reports for EC-77-5-05-5553

Work continued on the hookup to load for the 8V71T engine. The clutch-transmission-dynamometer installation was completed. The engine cooling water system and the dynamometer water supply systems were installed. Large leaks were found in the heat exchange system and these were repaired. A cooler for the fuel system was designed and is currently being machined.

The five transducer assembly for the Deutz diesel was tested with all pressure transducers installed. The five tube connections to the main cylinder head fitting were too weak in the face of the engine vibration, and the assembly failed. A redesign was made to stiffen the entire structure of the assembly and a new device is being manufactured.

Word was received from the DOE contract office that the paper work for the next funding increment has been initiated. Accordingly, steps have been taken to assure continuity of work on the project.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. G. Hammer
T. M. Dyer

December 7, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Seventeenth monthly progress report for EC-77-5-05-5553

Work continued on the connection of the clutch-transmission-dynamo to the Detroit Diesel 8V71T engine. However, the lack of funding slowed the effort since one engineer was transferred to another project. The entire effort is now being carried on institutional funding.

The five transducer pressure assembly was checked out and found to be defective in two transducer channels, due to the transducer-cable assemblies and not the apparatus. One new cable was ordered and has been received. Initial tests with this configuration will begin this month.

Sincerely,

Warren C. Strahle
Principal Investigator

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cc: J. C. Handley
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

November 8, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Sixteenth monthly progress report for EC-77-5-05-5553

Data reduction on the initial runs of the Detroit Diesel 8V71T engine was completed. The machining on the 5-tube pressure transducer assembly was completed. Theoretical work on the extraction of turbulence properties from the pressure measurement continued.

An error was discovered in the reported findings in the last monthly progress report. The results reported were at 2300 RPM, no-load rather than at idle. Data reduction was completed for three runs, all at no load; these were at 500, 1370 and 2300 RPM. Moreover, data reduction for the motoring condition (fuel shut off to cylinder number R1) at the same speeds was completed. The data at the idle condition of 500 RPM had to be rejected because there was no evidence of combustion in the monitored cylinder. Evidently, an injector setting was at fault.

There was little difference between the motoring and fuel-on runs. Upon looking at the p-t trace there was also little combustion taking place even at the full speed condition. Interestingly, the fraction of sound output coherent with the R1 cylinder pressure was high and the fraction of the sound due to randomness was also high. However, to get interesting combustion results will require that the engine be loaded up. Efforts in this direction were initiated.

Sincerely,

Warren C. Strahle
Principal Investigator

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cc: J. C. Handley
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DANIEL GUGGENHEIM SCHOOL
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October 4, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington, D.C. 20545

Subject: Fifteenth monthly progress report for EC-77-5-05-5553

The first runs on the Detroit Diesel 8V-71T engine were completed and preliminary results at one condition were obtained through Fourier analysis. A contractor's meeting was attended and results were reported for the previous year's activity. Work continued on the extraction of turbulence properties from the cylinder pressure measurement.

The Detroit Diesel engine installation was approved by Dixie Engine. Final modifications made were installation of several pressure and temperature guages, throttle control and the optical encoder. Runs were made at no load over the full speed range of the engine with the following instrumentation: a) cylinder pressure in cylinder # 1, b) optical encoder at 1 pulse/CA^{o}, 1 pulse/360 CA^{o} and frequency to voltage conversion, c) noise at 1m to the side of the engine. Motored runs were also conducted by removing fuel from cylinder # 1 and running on 7 cylinders. Data reduction was completed for the idle condition.

The results at idle are surprising. The cylinder pressure becomes random above 500 Hz, whereas the previous Deutz diesel results were only random above 1000 Hz. Moreover, there was fair coherence between the noise and the single cylinder pressure measurement. Of the coherent noise, 64% was random. We are anxiously awaiting the data reduction at the other condition to see if this difference between the two stroke and the four stroke engines persists.

The relatively high coherence between the noise and the single cylinder measurement are prompting the formulation of plans for multicylinder, multiple coherence measurements. Moreover, the high randomness on the Detroit Diesel engine suggests the use of this engine for investigation of turbulence through pressure measurements.

Machining was initiated on the five-tube pressure transducer assembly.

Supplies funds have been exhausted and personal services funds will become exhausted in December. At that time, if word of the next funding increment is not received, personnel layoffs will be incurred.

Sincerely,

Warren C. Strahle
Principal Investigator

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cc: J. C. Handley
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T. M. Dyer

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

September 5, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington DC 20545

Subject: Fourteenth monthly progress report for EC-77-5-05-5553

Work on set-up of the Detroit Diesel 8V71 engine has been completed. Two heat exchangers were adapted to use for the engine cooling water. The laboratory cooling water system was modified for hookup to the system. Complete reassembly of the engine was affected and the exhaust line to the building exterior was installed. All valve and injector settings have been completed. We are waiting for Dixie Engine (a GM representative) representative to check out the engine. Initial tests at no load over a range of speed will be completed this month.

A design was submitted to the machine shop for a five-transducer assembly for simultaneous measurement of pressure at five closely spaced cylinder points on the Deutz diesel. What is aimed at is a direct demonstration that in certain frequency ranges the cylinder pressure is not uniform across the cylinder, but that spacewise variations, random in nature, actually occur. The design for this probe is based upon the results, reported last month, on the extended tube probe. Fabrication will take about one month.

A paper on the results to data on the Deutz diesel was presented at the 17th International Combustion Symposium.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

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DANIEL GUGGENHEIM SCHOOL
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August 4, 1978

Dr. J. W. Birkeland
Division of Fossil Fuel Utilization
Department of Energy
Washington DC 20545

Subject: Thirteenth monthly progress report for EC-77-5-05-5553

The Fourier analysis of the cylinder pressure measurements with the transducer located either in the head or at the end of a connecting tube was completed. Three conditions were analyzed - idle (1000 RPM, no load), mid-range (1800 RPM, 17 ft-lb torque) and maximum speed (3000 RPM, 23 ft-lb). The objective was to see if a linear transfer function exists between the two measurement points. Division of the two auto spectra should give the square of the magnitude of the transfer function. Division of the transfer functions between the two pressure measurements and the head vibration should give the magnitude and phase of the desired transfer function. Comparison of the two derived magnitudes should indicate the "goodness" of the assumption that the linear transfer function exists. In all cases it was found that such a relation does exist, although the mid-range condition gave the best results. This result was surprising and highly satisfying. It opens the door for multiple point measurements of the cylinder pressure and deduction of several characteristics of the turbulence of the combustion process.

Work has continued on the set-up of the 8V71 Detroit diesel. All gaskets, seals and special tools were obtained for complete reassembly of the engine. A laboratory modification to the cooling water supply was judged necessary, and, since this must be done by the Georgia Tech Physical Plant, some delay will be encountered. Some machining on the optical encoder adapter flange and exhaust gas adapter flange remains to be done.

The major task for the 14th month is to complete set-up of the 8V71 and obtain idle, no-load data on the cylinder pressure.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
W. Hammer
T. M. Dyer

228 Report

July 10, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Twelfth Monthly Progress Report for EC-77-5-05-5553

Nine runs were made at various load and speed conditions on the Deutz diesel with the regular cylinder pressure transducer and the one with a tube between the cylinder pressure sensing point and the actual transducer. The purpose is to see whether or not a transfer function can be derived between the two measurements. The tube arrangement is the only design concieved for multiple sensing points without excessive head damage.

The magnitude of the transfer function can be obtained by comparing the two spectra. The phase, although it may not even be needed, presents a more difficult measurement problem. A unique method has been devised for this measurement based upon looking at the transfer functions of the two pressure measurements against a common element - the cylinder head vibration measurement. The Fourier analysis of the nine runs will be completed this month and the adequacy of the method will be evaluated.

Some shop delays have delayed the start up of the Detroit Diesel V71. The optical encoder flange, and exhaust gas adapter flange are still to be fabricated, although the head machining and transducer holder fabrication are complete. The engine has been mounted on the test stand. Some delay has also been encountered in the cooling water set-up. Before start-up, a certification will also have to be supplied by a General Motors representative. Consequently, it now appears that a useful data-taking run will be delayed until mid-August.

A closer look at the planned set of accleration runs on the Deutz diesel revealed ambiguities in the meaning of the type of Fourier analysis we have been conducting. Consequently, the acceleration runs will not be made.

The tasks for the 13th month include a) continuation of set-up of the V71 engine and b) Fourier analysis of the runs with the special transducer mount.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj
cc: J. C. Handley
W. Hammer
T. M. Dyer

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

June 8, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Eleventh Monthly Program Report for EC-77-5-05-5553

The test stand for the Detroit Diesel V71 has been completed, the pressure transducer mount has been finished, and the cooling water and exhaust apparatus has been procured. The head is in set-up in the shop for machining. It appears that by the end of the current month the engine will be ready for start-up and no-load testing.

The Fourier analysis of the timing variation and ethyl alcohol additive runs was completed. There were no strong trends in overall noise output with either of these variables. Moreover, the randomness of combustion was not strongly altered. The results at mid-load and mid-speed were that between 25 and 50% of the noise output could be ascribed to cylinder pressure randomness, as previously observed at the nominal timing and Diesel fuel condition.

Construction was completed on a special tube adapter for the pressure transducer mounting hole on the Deutz diesel. The objective here is to see whether a calibration can be achieved between the actual cylinder pressure and the pressure at the end of a long (4"), narrow (3/16") tube. This is necessary if a five tube system is to be installed in the current transducer hole; this set-up is desired in order to extract heat release rate fluctuation data in the cylinder. The theoretical work for the month indicates that ten cross spectral densities from five transducers will be sufficient to extract the necessary fluctuation data. The calibration run will be made during the current month.

A set of runs on the Deutz engine under accelerating conditions is planned for the current month. It is known that dramatic changes take place in overall level of the cylinder pressure spectra under such conditions and it is desired to see if the randomness of the trace is altered under such conditions.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
M. Muthukrishnan
T. M. Dyer
W. Hammer

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

May 5, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Tenth monthly progress report for EC-77-5-05-5553

All machine work for the test stand for the Detroit Diesel V71 has been completed, and the parts are in place awaiting welding. Machining of the pressure transducer holder for cylinder # 1 was begun and the cylinder head is awaiting finishing machining.

Two strain gages were mounted on the fuel line on the Deutz Diesel. This technique proved successful as an indicator of injection timing, so a set of runs was made at five different timing conditions. Instrumentation included cylinder pressure, crank angle, head acceleration, frequency to voltage conversion (speed), three sound microphones, fuel flow, and two strain gages. As check runs to compare with previous data, two runs were made at maximum power and the baseline condition (1800 RPM, 17 ft-lb torque). Commercial fuel was used.

In order to modify the combustion process considerably, ethyl alcohol was mixed with the Diesel fuel in 5% increments from 0-30 %. Six runs with the above instrumentation were made at the baseline condition. All data are currently being subjected to Fourier analysis.

The major tasks for the eleventh month are a) to complete the V71 test stand and cylinder head work and b) to complete Fourier analysis and interpretation of the above tests.

An effort has been reinitiated to determine the feasibility of measurement of the mean square, spectral distribution and spatial correlation length scales of the heat release fluctuation. This is to be accomplished by multiple pressure measurements inside of the cylinder and through use of prior theoretical developments. A senior graduate student is undertaking this task.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: J. C. Handley
M. Muthukrishnan
T. M. Dyer
W. Hammer

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

April 7, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Ninth monthly progress report for EC-77-5-05-5553

The second funding increment has now been received and work has started again on the project.

The next test sequence on the Deutz Diesel will vary the injection timing. To this end, strain gages have been procured for mounting on the fuel line in order that a measure of injection timing variations may be made. These gages have been received and mounted. The test sequence should be completed during the current month.

The Detroit Diesel V71 with the special heads is in a set-up process. The mounting for the cylinder pressure transducer is being fabricated and the head is being machined. The test stand has been designed and the material procured. Construction of the test stand is underway.

A paper submitted to the 17th Combustion Symposium was accepted and the paper was written during the past month.

Sincerely,

W. C. Strahle
Principal Investigator

cc: J. C. Handley
M. Muthukrishnan
T. M. Dyer
R. M. Law

WCS/cj

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

March 3, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Eighth monthly progress report for EC-77-5-05-5553

The same problem as reported in the last three progress reports, that of delayed delivery of the next funding increment, has become acute. Not only have supplies monies been absent but personal services monies have been exhausted. Consequently, until the next increment arrives, personnel have been shifted to other programs. There is no substantive progress to report for this period.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

March 3, 1978

U. S. Department of Energy
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D.C. 20545

Subject: Seventh monthly progress report for EC-77-5-05-5553

The same problem as reported in the last three progress reports, that of delayed delivery of the next funding increment, has become acute. Not only have supplies monies been absent but personal services monies have been exhausted. Consequently, until the next increment arrives, personnel have been shifted to other programs. There is no substantive progress to report for this period.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

February 7, 1978

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Sixth monthly progress report for USERDA
Contract No. EC-77-5-05-5553

The same financial problem as reported during the past two months still exists. The next funding increment has not arrived so that supplies funds are absent. The Detroit Diesel V71 is ready for set-up and instrumentation installation, but no funds are available.

Analysis was continued with old data tapes to clear up some problems in interpretation of the data. The techniques used were a) extremely short time window analysis containing only the ignition spike, b) spectral comparisons of the compression-power stroke with the exhaust-intake stroke, c) triggering of the Fourier time window on pressure rather than crank angle and d) comparison of a high Cetane (low randomness) run with a low power, Diesel Oil No. 2 (high randomness) run. The results may be summarized as follows:

a) Randomness or non-repeatability of the pressure-time trace exists for our direct injection engine, but it is only strong at low power and low to moderate speed. When it is significant it may be easily discerned by visual examination of successive p-t traces. The randomness occurs during ignition and combustion.

b) Apparent randomness during the exhaust and intake strokes is high frequency vibration sensitivity of the pressure transducer.

c) Low randomness at high load, speed and Cetane rating may be unique to the DI method, since high randomness has been observed by other workers with IDI engines.

d) Any degree of randomness will cause a higher noise output at a given engine power output. This has been found significant with our engine, however, only at low power.

e) The signal processing techniques used here can be used as an engine combustion quality diagnostic.

With a view toward forcing a higher degree of cylinder pressure randomness, the small engine will be set up for a test series with a

variable injection timing. This set-up will occur during the coming month.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

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SCHOOL OF
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404-894-3000

DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

January 4, 1978

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Fifth monthly progress report for USERDA Contract No. EC-77-5-05-5553

During the past report period two major events have hampered progress. These were both financial and technical. First, the lack of the next increment of funding has stalled all rebuilding work and the bringing of the Detroit Diesel V71 on line. There are no supplies funds for this purpose. Secondly, a significant reinterpretation of our results may be in order upon a close examination of past tapes.

Because of the lack of supplies funds, all work currently centers upon more careful analysis of past tape-recorded results. In looking at a comparison of a typical p-t diagram with a 100 cycle average there are several interesting features which have not been observed before, when observing the random deviations from the mean. Near the ignition spike the strongest random deviation of a single trace from the average will usually occur. However, away from the combustion portion of the trace there are indicated $\pm$ 10 psi pressure fluctuations even when the exhaust valve is opened. This is clearly an impossible situation.

Spectral analysis of the random trace away from the combustion portion of the trace reveals a frequency content previously proven to be dominated by the vibration response of the pressure transducer. In the portion of the trace dominated by combustion the frequency content coincides with that previously attributed to combustion noise. However, it has become apparent that the random deviations of each p-t diagram from the average in the combustion region is due to a variation in ignition delay from firing to firing. Since triggering is performed on crank angle, the apparent ignition delay variations can be caused by a) a lack of speed control or b) a true variation in ignition delay. Speed control has been addressed before and has been dismissed as a factor. However, the major finding is that combustion (random) noise is probably not significant in the noise problem but variable ignition delay is. A re-analysis of the cetane variation runs is being made to confirm this point.

A major practical point of this determination is that, if high randomness in the ignition delay is present, it is worthless to examine an average p-t diagram for noise output purposes. It is possible that an engine can have a high dp/dt in the ignition spike on each firing but when averaged over a large number of firings a low dp/dt will result - giving an erroneous

interpretation. It therefore appears necessary to have an idea of both randomness and average p-t behavior to properly interpret noise results. This point will be explored during the next report period.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

6-28 Report

GEORGIA INSTITUTE OF TECHNOLOGY
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SCHOOL OF
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DANIEL GUGGENHEIM SCHOOL
OF AERONAUTICS

November 4, 1977

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: Fourth monthly progress report for USERDA Contract EC-77-S-05-5553.

During the past report period the major tasks were a) analysis of the vibration sensitivity of the cylinder pressure transducer, b) a repeat test sequence for vibration sensitivity of a new transducer, c) analysis of the noise-cylinder pressure coherence and d) continuation of rebuilding of a two stroke Diesel engine.

It was found that our AVL pressure transducer does, in fact, have vibration response, but that only above 3500Hz does the vibration signal dominate the pressure signal. Consequently, all previously reported results are believed valid to 3500Hz (above which there is no noise problem anyway). To check the generality of this result another test sequence with a capped and uncapped transducer has been conducted with a new transducer. The result will be analyzed during the forthcoming month.

The poor coherence between the noise output and the cylinder pressure which was obtained on the last Cetane rating test sequence has been traced to the acoustic environment of the test room. A microphone location is being sought that will reproduce the high coherence of earlier runs. Moreover, the accelerometer pickup will be favored in the future for showing the causal relation between cylinder pressure and noise.

The rebuilding of the two stroke, two cylinder engine hit a snag when sealing problems between the oil and water lines arose. The cut for the pressure transducer sliced both lines and a satisfactory seal has not been found. We are currently turning the engine into a one-cylinder engine and drilling a more satisfactory pressure access hole in the remaining cylinder.

Delivery of an eight cylinder Detroit Diesel engine has been taken on consignment from General Motors. The engine is complete with drilled head, transmission, clutch, and dynamometer. The cost of set-up will be assessed during the coming month.

Analysis of the combustion randomness-noise relation by a new computational technique has shown that, at mid-load, as much as 75% of the noise output can be directly traced to the combustion randomness. This technique will now be applied to data of previous Cetane rating runs.

Sincerely,

W. C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
J. C. Handley
T. M. Dyer

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DANIEL GUGGENHEIM SCHOOL
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October 6, 1977

USERDA
Attn: J. W. Birkeland
Division of Conservation Research and Technology
Washington, D. C. 20545

Subject: First through third monthly progress reports for USERDA contract number EC-77-S-05-5553.

Funding was received in September for the program back-dated to July 1, 1977. For this reason this report covers a three month period. Activity did take place during the summer, although at a reduced pace compared with current activity. The primary tasks were a) familiarization of a new post-doctoral fellow with the Diesel engine equipment and instrumentation b) rebuilding and pressure-sensor installation on a two cylinder, two stroke engine c) conduct of tests to determine acceleration sensitivity of the AVL pressure transducer, and d) Fourier analysis of past results with a focus on the ignition spike portion of the pressure-time trace.

Briefly reviewing, the prior NSF program had conclusively proven that a) the p-t diagram on a single cylinder Deutz engine is sufficiently non-repeatable from cycle to cycle to cause b) a substantial random component to the noise output from such an engine. This non-repeatability has been ascribed to the turbulence of the combustion process. Four fundamental questions existed at the termination of the NSF program. These were a) is the randomness-noise relation primarily driven by the ignition spike or does it come over a large number of crank angle degrees, b) is the randomness due to a randomness in ignition delay or a true randomness in development of the full p-t diagram, c) is the randomness a true property of the p-t diagram or is it caused by vibration sensitivity of the pressure transducer and d) what was the cause of the drop in coherence between the cylinder pressure and noise output during the last run sequence of the NSF program? The initial efforts on the current program are to answer these questions.

Fourier analysis of past results has shown that, indeed, the violent ignition spike contains the primary randomness in the p-t diagram development. Moreover, it is not purely ignition delay randomness but randomness in the full development of the spike that is primarily responsible.

A test sequence has just been completed for vibration sensitivity of the pressure transducer. This data will be analyzed during the next month.

The coherence loss during the runs at high load and with various Cetane fuels is suspected to have been caused by a tape recorder problem. A switch in recorders to a new one with better phase-preservation characteristics has been made. The Cetane rating runs will be repeated, starting next month.

Detroit-Diesel has verbally committed to delivery of an 8-cylinder, two stroke truck engine. Delays in receipt, however, have prompted us to rebuild a two-stroke, two cylinder engine which is on hand. The purpose here is to check the randomness of combustion on a two-stroke cycle as compared with that of the four stroke engine currently in use. This rebuilding process should be completed by mid-October.

The exact plans for the future depend heavily on the outcome of the vibration sensitivity tests for the pressure transducer. Anticipating that a true combustion randomness is being measured, the priority item is a repeat of the Cetane rating runs.

Sincerely,

Warren C. Strahle
Principal Investigator

WCS/jj

cc: M. Muthukrishnan
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